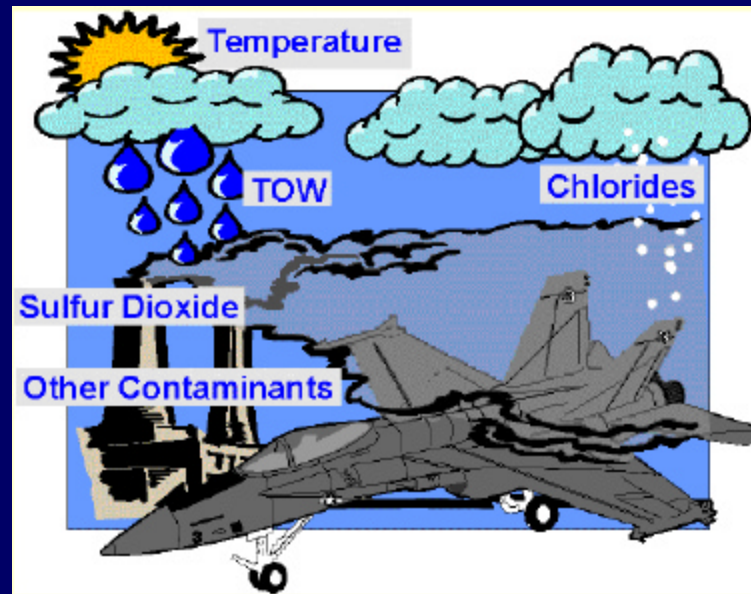


A System Engineering Approach to Creating An Effective Corrosion Inspection Regimen



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Current Approach to Corrosion Maintenance

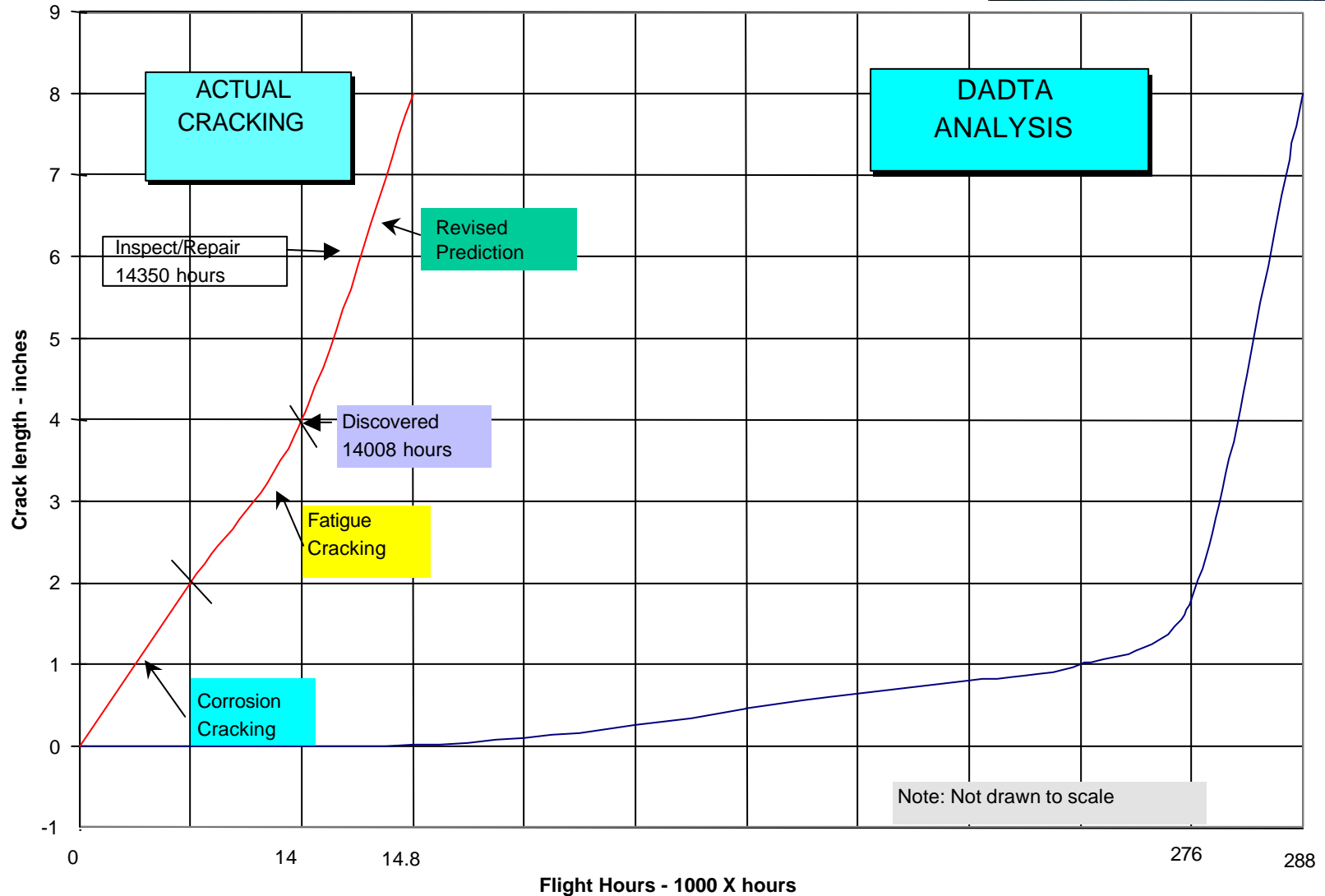
- If you have a known corrosion problem, inspect every aircraft, every time, to ensure that all deficiencies are detected and corrected.
- In the absence of a known problem, count on fortuitous discovery to catch problems before you lose an aircraft or something equally serious happens
- Corrosion is an economic problem; not a safety issue

Some Recent Experience

- Corrosion failures on the:
 - C-5
 - F-15
 - F-16
- Hoepfner Results



C-5 Experience



F-15 Experience



- Two Langley AFB aircraft at WR-ALC for PDM were found with major corrosion problems
 - Fuel tank floors, skins and stringers replaced
- Structure degraded in transverse load carrying capability
- Structure degraded in negative-g load carrying capability
- Fleet wide inspection





F-16 Experience



- RNAF technician found the external pylon fitting rotating freely in the wing due to extensive corrosion damage.
- Potential result - dropped object or loss of a/c.
- Extensive depot repair procedure imposed on a significant number of wings/aircraft.

Hoepfner Results

- REVIEW OF PITTING CORROSION FATIGUE MODELS: ICAF-99
 - Review of aircraft incidents and accidents since 1983. 91 incidents and accidents were found to be caused by corrosion
- CORROSION AND FRETTING AS CRITICAL AVIATION SAFETY ISSUES: ICAF-95
 - At least 687 corrosion related incidents and accidents on civilian and military aircraft in the United States since 1975. In these accidents, 87 aircraft have been destroyed, and 81 lives have been lost.

Experience Tells Us..

- Corrosion failures cost lives and aircraft
- Corrosion damage in critical structure can create an initial flaw that greatly reduces safe life predictions
- Corrosion damage can render structural analysis invalid - and change component status from non-critical to critical
- Discovery of critical corrosion damage is too often fortuitous

Experience Tells Us..

(cont)

- We need a better approach to corrosion inspection

A Better Approach Is Available

Use system engineering techniques and current analysis methods to develop a timely, thorough approach to corrosion inspection requirements on critical structure.

Elements

- ASIP Analysis (to identify critical structure)
- Corrosion Prone Areas
- FMEA
- RCM
- Individual Aircraft Tracking Program
- Environmental Severity Index

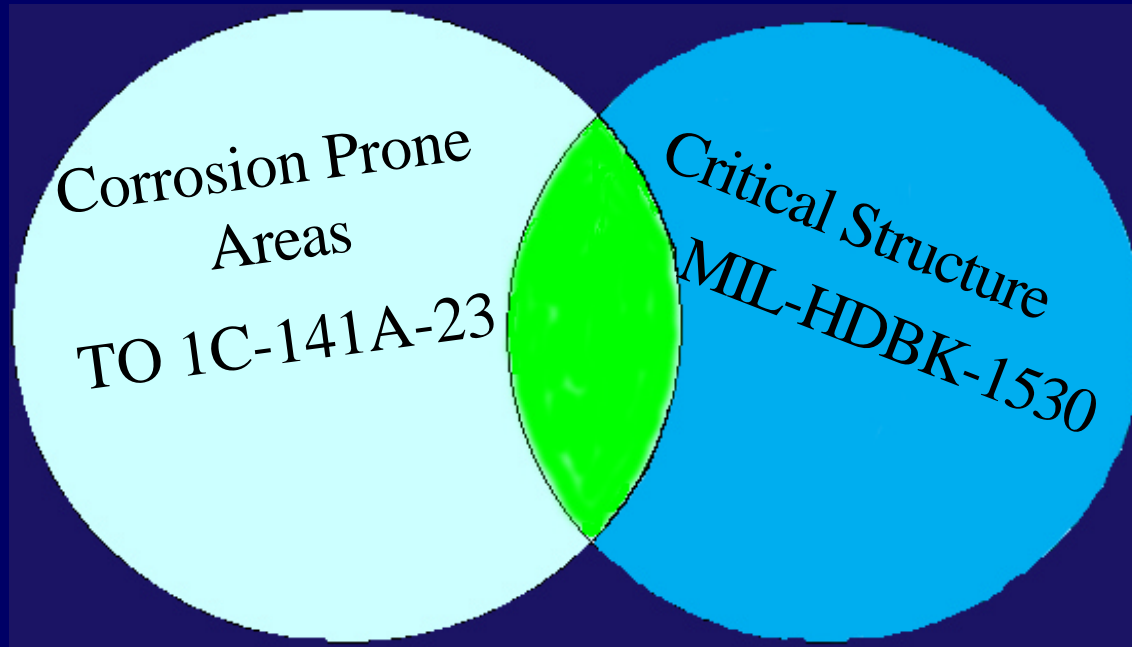
Elements (cont)

- Cumulative Corrosion Exposure
- Lead - the - Fleet Aircraft
- Analytical Condition Inspection (ACI) selection
- Corrosion Inspection Program
- Treatment of results from ACI inspection

Completed ASIP Analysis

- Aircraft Structural Integrity Program analyses used to identify/classify aircraft structure.
 - Critical Structure – failure could result in accident or loss of aircraft
 - Primary/Secondary Structure classifies structure by its importance to safe flight or mission
 - Identifies structural inspection requirements for critical structure through detailed fatigue analysis

FMEA/RCM



- Corrosion Prone Areas
- FMEA of the intersection of corrosion prone areas and critical structure
- Reliability Centered Maintenance analysis of FMEA results

Corrosion Prone Areas

- TO 1x-xxx-23
- Corrosion Prone Areas identified
 - Materials used
 - Finishes used
 - Environmental exposure
 - Experience

FMEA Analysis

- FMEA traditionally used to analyze failures of mechanical/electrical subsystems
 - Employs very structured analysis procedures
 - Employs very structured definitions to ensure thoroughness
 - Identifies failure effects on higher level systems
- Modify slightly to examine the effects of corrosion on critical/primary structure
 - Define corrosion failure

Reliability Centered Maintenance

- Technique used to establish inspection requirements based on safety, mission, and observability of failures
 - Generally used on mechanical and electrical sub-systems
 - Very infrequently uses time as a sole criterion for action
- Establish corrosion inspection requirements

Cumulative Corrosion Exposure

- Individual Aircraft Tracking Program
- Aircraft corrosion damage is a reaction of the structural material with the corrosive effects of the environment
 - Environmental Corrosion Severity
 - Time on station

$$CCE = \sum_{bases} ESI * t$$

Lead-the-Fleet Aircraft

- A group of aircraft whose operations are controlled so that their flight hours are always well ahead of the fleet average.
 - Inspect regularly
 - Inspect more in-depth
 - Aid in establishing depot inspection requirements
 - Widely used in the commercial aircraft industry

Lead-the-Fleet Aircraft (cont)

- Modify slightly to establish corrosion LTF aircraft such that their CCE is and remains significantly greater than other fleet aircraft CCE

Analytical Condition Inspection

- Aircraft in depot maintenance are chosen to undergo additional in-depth inspection
 - Typically 10% of depot visitors or 6 a/c whichever is more – each year
 - Additional structural inspections
 - Additional mechanical and electrical systems

Analytical Condition Inspection (cont)

- Modify so as to choose annual ACI aircraft from LTF aircraft among depot inputs with highest CCEs
- Modify so as to add corrosion inspections to regular ACI requirements

Treatment of ACI Hits

- None – Re-calculate threshold CCE and continue ACI inspections
- Minor – Expand ACI inspection base to ensure adequate coverage
- Major(1) – Inspect all aircraft with equivalent CCE index

Treatment of Hits (cont)

- Major (2)– Schedule depot inspections on aircraft as they reach the CCE index that indicates need
- Conversely – Do not schedule depot inspections on aircraft that have not reached the index

Corrosion Inspection

- Combine all the previous elements to establish a corrosion inspection regimen that is based on real requirements and observed deficiencies.
 - Where to inspect
 - Results from ASIP/FMEA/RCM analysis
 - What to inspect for
 - FMEA results
 - When to inspect
 - During ACI
 - During PDM for known problems
 - What to do next
 - Standard ACI rules for expanded inspections

Conclusions

- Corrosion damage has contributed to structural mishaps causing aircraft accidents and loss of life.
- Frequently, preservation of aircraft safety and mission reliability relies on fortuitous discovery of critical corrosion damage.
- A corrosion inspection regimen such as that outlined will result in greater operational availability and assurance of aircraft structural integrity.

Benefits

- No inspections outside of ACI until an aircraft reaches a CCE threshold*
- Repeated reinforcement of the results of analysis ensure that nothing is missed
- Inspections are affordable until fleet reaches critical CCE limit

*Exception – Stress Corrosion Cracking or Corrosion as a result of mission or operations conditions, e.g., galleys, lavatories, airborne laser operation

Benefits (cont)

- Shorter depot visits = More available airframes
- Known depot requirements for repair = \$ savings
- Simplified cost of ownership calculations